FLAME CULTIVATION

EQUIPMENT AND TECHNIQUES

Production Research Report No. 86

Agricultural Research Service

UNITED STATES DEPARTMENT OF AGRICULTURE

in cooperation with

Mississippi Agricultural Experiment Station

CONTENTS

Washington, D.C. Issued February 1965

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402 - Price 15 cents

FLAME CULTIVATION EQUIPMENT AND TECHNIQUES[1]

By R. E. Parker, *agricultural engineer, Agricultural Engineering Research Division*; J. T. Holstun, Jr., *agronomist, Crops Research Division*; and F. E. Fulgham, *agricultural engineer, Agricultural Engineering Research Division, Agricultural Research Service*

INTRODUCTION

The need to fully mechanize and reduce the cost of producing crops on the farm has increased the use of flame to control harmful weeds in row crops. The successful use of flame in weed control depends mainly on the relative flame tolerance of the crops and the weeds. Flame's effectiveness, however, depends on how precisely it is applied. Accurate control of the flame path must be maintained at all times, and the speed of travel must be adjusted according to the heat intensity of the flame and the heat tolerance of the row crop.

The use of flame in crop cultivation has tended to increase as the use of chemicals for weed control has increased. The reason for this is that flame is an effective supplement of chemical and other forms of weed control. Holstun and others (*4*) [2] found that flame cultivation used alone saved only $0.83 per acre in weed-control costs for cotton in 1958. However, when used in conjunction with preemergence and postemergence herbicides, flame cultivation saved $5.66 per acre in total weed-control costs.

BASIC FLAME CULTIVATION EQUIPMENT

All flame-cultivation equipment has the following basic components: (a) Fuel tank, (b) fuel withdrawal valve, (c) quick shutoff valve, (d) pressure regulator, (e) pressure gage, (f) fuel feeder lines, (g) burner carrier, and (h) burners. A fuel vaporizer, or heat exchanger, is optional and is not needed if self-vaporizing burners are employed. The assembly order of a basic flame cultivator is illustrated in figure 1. Following the introduction of liquefied petroleum gas (LPG) equipment for farm use in 1945 (*12*), the major changes in flame cultivation have been those related to the design of burners and burner carriers.

FUELS

TYPES AND PROPERTIES

Propane and butane have been used extensively as fuel for flame cultivating since 1945. They must be stored under pressure in large bulk tanks on the farm. Although propane and butane produce approximately the same amount of heat (B.t.u.) per pound, they differ in some of their properties (table 1) (*7*). Propane vaporizes at a much lower temperature than does butane. However, tank pressure keeps both fuels in the liquid state. Less supplemental heat is required to vaporize propane than butane.

Table 1.—*Properties of propane and butane*

Properties	Propane	Butane
Formula	C_3H_8	C_4H_{10}
Molecular weight	44.1	58.1
Specific gravity [1]	.582	.570
Melting temperature [2] ° F	−306	−217
Boiling point [2] ° F	−44	31
Self-ignition temperature [2] ° F	995	961
Heating value [3] B.t.u./lb. (higher)	21,650	21,300
Air-fuel ratio for perfect combustion	15.6:1	15.4:1

[1] Density determined at the boiling point of the liquefied gas.
[2] At 14.7 p.s.i. absolute or atmospheric pressure.
[3] Heating value at constant volume from 77° F.

[1] The research described is part of a contribution to Regional Cotton Mechanization Project S–2.

[2] Italicized numbers in parentheses refer to Literature Cited, p. 16.

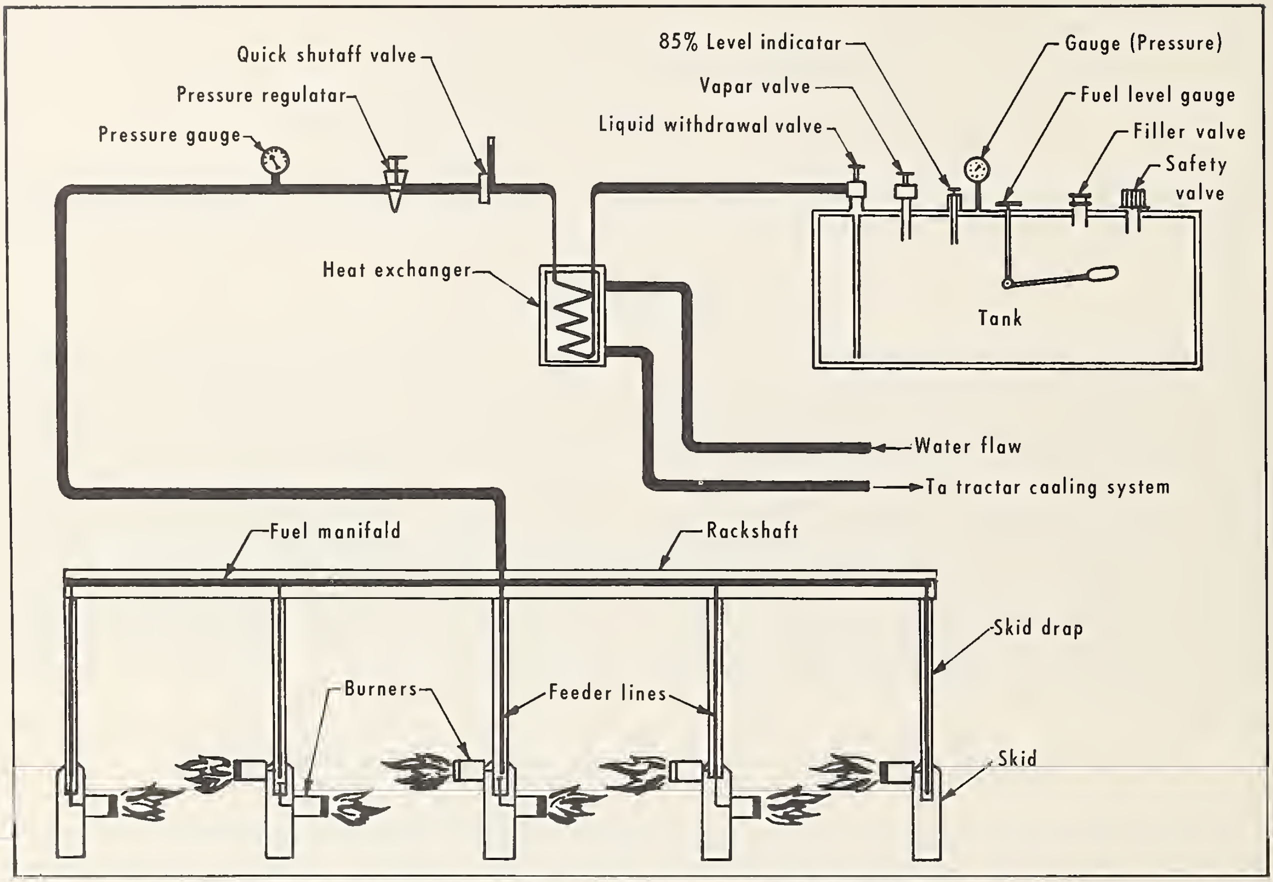

Figure 1.—Assembly-order diagram of four-row flame cultivator equipment. The heat exchanger is not needed if self-vaporizing burners are used.

Flame temperatures of propane and butane are 1,925° and 1,895° C. respectively (*6*). Propane is generally more desirable than butane as a fuel for flame cultivation, but both gases must be vaporized to obtain maximum burning efficiency. Consequently, preference depends upon the availability and cost of these fuels.

FUEL CONSUMPTION AND FLAMING COSTS

The amount of liquefied petroleum gas consumed in flame cultivating a 12- to 16-inch band under the row crop normally ranges from 4 to 6

gallons per acre, depending upon the age and denseness of the weeds to be burned. Based on a cost of 10 cents per gallon, the fuel to flame cultivate an acre costs from 40 to 60 cents. However, local fuel prices vary considerably, depending on their availability, demand, and other factors. Therefore, costs of flaming must be based on local prices because fuel is the main item of expense. The overall cost of flame cultivation (labor, material, and machinery) in the Midsouth was estimated by Holstun and others (*4*) to average $1.25 per acre per application. Williamson and others (*12*), estimated that overall flaming costs range from $0.70 to $1.20 per acre per application, depending upon the size of the machine and speed of operation.

Williamson and others (*12*) have determined the flow capacities for several sizes of orifice tips used on burners (table 2). The double-orifice nozzle size 2–2503 is most commonly used on flat-type burners.

Table 2.—*Propane flow capacity of five standard orifice tips used in flat-type burners of flame cultivators*

Orifice-tip No.	Line pressure	Fuel consumed per burner [1]	Fuel consumed when cultivator is moved at a speed of [2] 2 m.p.h.	3 m.p.h.	4 m.p.h.
	p.s.i.	*Gal./hr.*	*Gal./acre*	*Gal./acre*	*Gal./acre*
2–2502	30	1.86	4.60	3.07	2.30
	40	2.15	5.32	3.55	2.66
	50	2.59	6.41	4.27	3.20
2–2503	30	2.68	6.63	4.42	3.31
	40	3.11	7.69	5.13	3.85
	50	3.65	9.03	6.02	4.52
4002	20	.75	1.83	1.22	.92
	30	1.20	2.97	1.98	1.48
	40	1.32	3.26	2.18	1.63
4004	20	1.52	3.76	2.51	1.88
	30	2.02	4.99	3.33	2.50
	40	2.25	5.57	3.71	2.78
4006	20	2.19	5.42	3.61	2.71
	30	2.86	7.08	4.72	3.54
	40	2.88	7.13	4.75	3.56

[1] A 4-row cultivator has 8 burners.

[2] Fuel consumption is based on 1 orifice tip per burner and 2 burners per 40-inch row. No allowance was made for turning.

FLAME CULTIVATION TECHNIQUES

CONVENTIONAL CROSS FLAMING

As a rule, the leaves of plants are much more sensitive to heat than are the stems. For this reason, flame cannot be used to kill weeds until the row crop is taller than the weeds. Therefore, some form of preflaming weed-control program must be used until the row crop has grown taller than the weeds. Preflaming treatment may consist of hoeing or applying preemergence herbicides or postemergence oils. The best weed-control program for cotton consists of a preemergence treatment followed by postemergence applications of oil and cultivation with flame (*1*).

Cross flaming requires the use of two burners per row. Flame cultivation of cotton starts when the cotton plants are 10 to 12 inches tall and have a stem diameter of approximately three-sixteenths of an inch. The burners may be set at an angle of approximately 45° with the ground level or as flat as 30° according to studies in California by Carter and others (*3*). For either setting, flame should strike the ground 2 inches from the base of the cotton plant.

The flame path from burners mounted rigidly in relation to each other toward plant rows that are growing on soil of equal and unequal elevations is shown in figure 2. Commercial flame-cultivation equipment utilizes the rigid system of

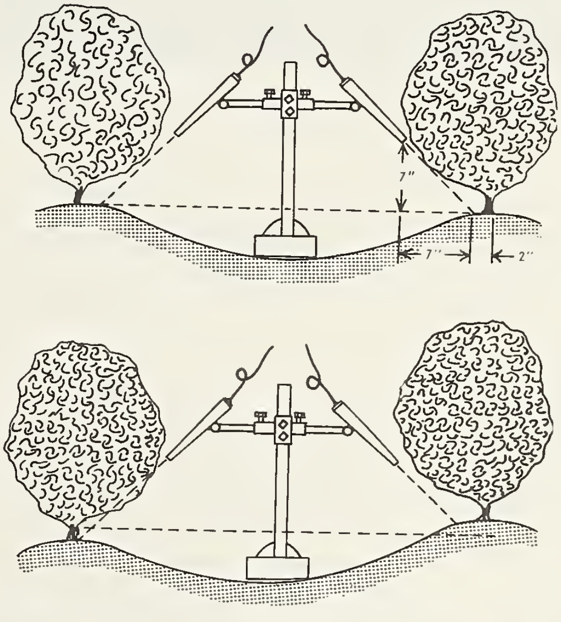

Figure 2.—Flame path from rigidly mounted burners set at an angle of 45°. Upper diagram shows path of flame when plant rows are on ground of the same elevation. Lower diagram, the path when adjacent rows are on ground of a different elevation.

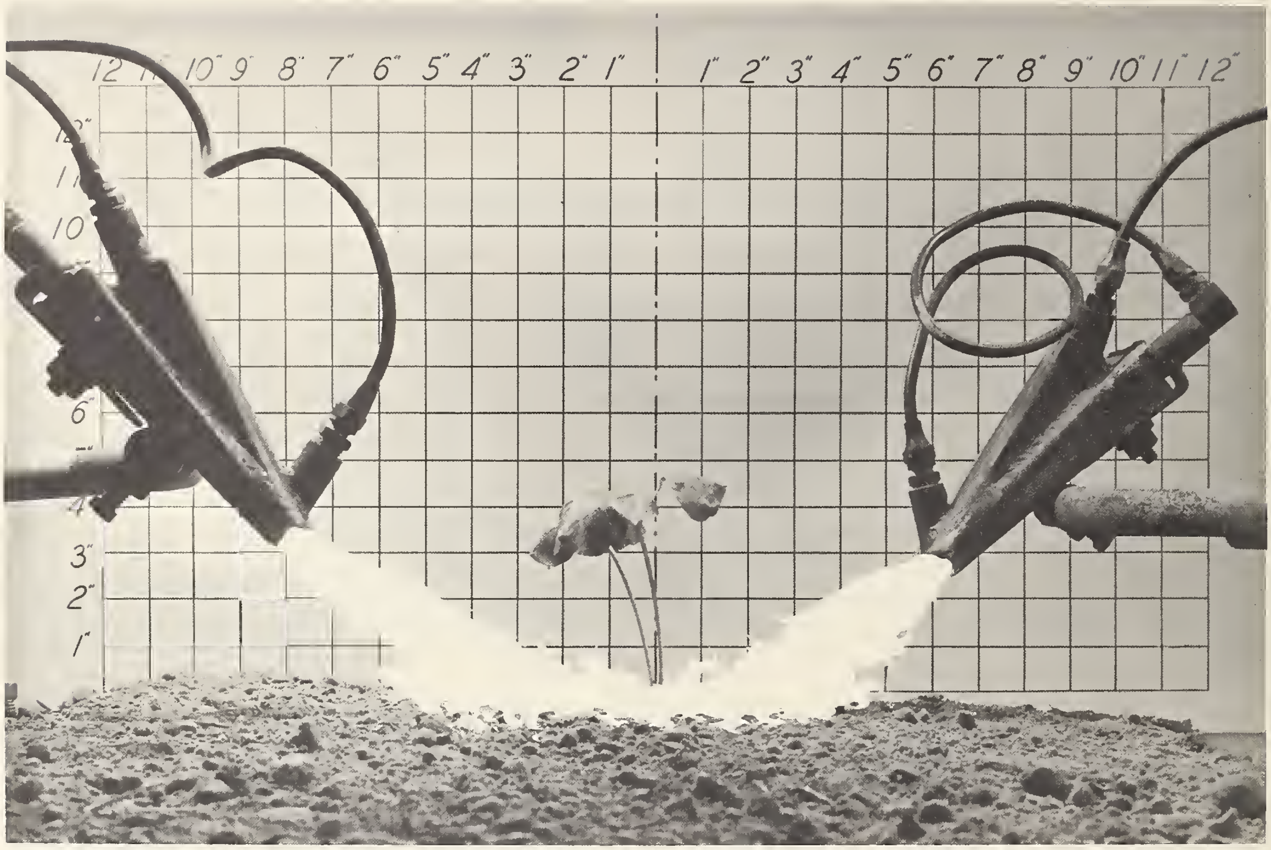

FIGURE 3.—Scaled-down version of the standard Stoneville flat burner developed in 1953 for flaming cotton that is 4 to 6 inches tall. A fuel vaporizing chamber is welded on top of burner.

of mounting burners. The disadvantages of mounting burners in this manner were discussed in detail by Parker and others *(10)* in connection with their work on gaging flame burners. Additional work on the mounting of burners is described later in this report.

The feasibility of flaming young cotton that is less than 10 inches tall has received attention by researchers. Small burners have been tried in efforts to increase the use of flame for weed control in cotton no taller than 4 inches. Research on small burners began at the Delta Branch of the Mississippi Agricultural Experiment Station in 1952. A small burner was designed and constructed to one-half the scale of the original Stoneville flat burner (fig. 3). A successful vaporizing chamber was welded on the burner to make it "self energized."

Laboratory tests on a scaled-down version of the standard size Stoneville burner in 1953 indicated it consumed fuel at the rate of about one-half that of the large burner and yet maintained the same flame temperature.[3] The fuel-consumption rates are given in table 2 for orifice tips numbered 4002 and 4004, which were used on both the small burner and the standard-size burner.

Although the small burner used about half as much fuel as the large burner and flame temperatures were about the same, the quantity of heat generated by the small burner was probably much less than that generated by the large burner. Thus, to obtain the same destructive effect, the flame of the small burner needs to be thrown on the weeds for a longer interval than that of the large burner.

Field tests in 1954 showed that, from the standpoint of plant damage, the small burners could be used safely on very young cotton (from 4 to 6

[3] Fulgham, F. E. Small flame burner developments. 1953. (Unpublished annual report of Regional Cotton Mechanization Project S–2.)

inches tall) if the cultivator were moved past the cotton plants at relatively high speeds.[4] On the other hand, flaming at high speeds resulted in a progressively reduced effectiveness on weeds. Flaming at the lower speeds successfully controlled weeds, but it severely damaged young cotton plants and reduced cotton yields (table 3). Adequate weed control with only a small amount of damage to plants was obtained at a tractor speed of 3.6 miles per hour. The economic feasibility of purchasing or constructing small burners for flaming young cotton was and still is a questionable procedure because of the plant-damage risks involved.

TABLE 3.—*The effect of flaming cotton 4 to 6 inches tall at stated speeds by use of small burners equipped with size 4002 orifice tips and operated at a pressure of 40 p.s.i., Stoneville, Miss., 1954*

Tractor speed (miles per hour)	Weed control	Seed cotton yield
	Weeds/acre	*lb./acre*
2.4	3, 052	1, 464
3.0	14, 824	1, 708
3.6	41, 420	1, 786
4.3	73, 684	1, 725
5.0	139, 956	1, 725
No flame, check	149, 548	1, 882

PARALLEL FLAMING

The practice of flaming with burners directed parallel to the row is relatively new. In Arkansas, Stephenson (*11*) obtained data that indicated parallel flaming is fully as effective as cross flaming and can be used safely when cotton plants are very small. Work in Mississippi by Parker and Holstun (*8*) showed that young cotton (at the 4-inch stage) was damaged less when burners were set parallel than when they were set for cross flaming. Burners mounted for parallel and cross flaming are shown in figure 4. The work in Mississippi also indicated that parallel flaming was more effective when combined with a preemergence application of herbicide than when used alone. Close observation of additional work on parallel flaming confirmed opinions that most of the weeds that had to be hoed from parallel-flamed plots were in the center of the drill row where parallel flaming had failed to destroy them.

FIGURE 4.—Burners in foreground are set for flaming parallel to the row—one burner on each side of row. Those in background, for cross flaming. The burners were used in these positions during tests conducted to compare results of parallel flaming with those of cross flaming.

Studies in 1962 in Mississippi indicated that parallel flaming of cotton at the 4- to 6-inch stage burned the cotton leaves as severely as did the cross flaming of cotton in the 7- to 10-inch stage. The damage to leaves was a temporary setback since all the cotton had recovered by midseason. Yields were not significantly affected by the early damage to leaves (table 4).

TABLE 4.—*Hoe labor required and seed cotton yield from plots treated with a preemergence herbicide and flame cultivated at various stages of growth, Stoneville, Miss., 1962* [1]

Treatment	Hoe labor required	Yield seed cotton
	Hr./acre	*Lb./acre*
Parallel flamed when cotton was 4 to 6 inches tall and when 7 to 10 inches tall; cross flamed as needed thereafter	4	2, 680
Parallel flamed when cotton was 7 to 10 inches tall; cross flamed as needed thereafter	5	2, 690
Cross flamed when cotton was 7 to 10 inches tall; thereafter cross flamed as needed	7	2, 760
Cross flamed when cotton was 10 to 18 inches tall; thereafter cross flamed as needed	12	2, 730
Hoed check	40	2, 740

[1] Average of five replications. Each plot (4 rows, 75 feet long) was flamed with individually gaged burners.

[4] Fulgham, F. E. Flame cultivation. 1954. (Unpublished annual report of Regional Cotton Mechanization Project S–2.)

The economic feasibility of parallel flaming of cotton early in the growing season may be questionable. Initial parallel flaming when cotton was in the 4- to 6-inch stage of growth saved only 1 hour of hoe labor per acre compared with initial parallel flaming when cotton was in the 7- to 10-inch stage (table 4). In an experiment of this kind, a 2-hour difference in the amount of hoe labor needed per acre is considered to be negligible. Early parallel flaming tended to damage the cotton. However, delayed flaming (in cotton 7 to 10 inches tall) was more successful overall for weed control and for crop tolerance when burners were set to throw flame across the row.

MIDDLE FLAMING

The latest weed-control recommendations for the middles of cotton rows in Mississippi emphasize the use of shielded mechanical cultivation to prevent moving soil into the drilled area under the following conditions: (a) If the control of weeds by previous chemical or flame treatment was completely effective, (b) if further directed sprays are to be applied to the drill row, or (c) if immediate flaming is planned (*5*). In addition, where there is reason for avoiding cultivation, the use of a new middle flamer (described later in this report) is tentatively recommended for the control of weeds in row middles.

Middle flaming of cotton may be beneficial under one or more of the following conditions: (a) If it is desirable that soil not be disturbed either in the drill rows or middles; (b) if mechanical cultivation is impractical because of frequent rains (fig. 5) or because the crop was planted in a recently cleared area in which many hidden tree roots exist; (c) if the cost of flaming is less than the cost of postemergence herbicides, which will do the same job required under conditions (a) and (b); or (d) if there is excess residual buildup of herbicide.

FIGURE 5.—Grass in the middles grew during wet weather that occurred before the field could be plowed. Middles were eventually cleaned by flaming.

FLAME CULTIVATION EQUIPMENT

FUEL TANKS

Fuel tanks are available in various sizes. The most commonly used size has a capacity of 100 gallons. All tanks should have brass fittings and meet certain code specifications of the American Society of Mechanical Engineers for handling butane and propane fuels. Figure 1 illustrates the fittings that are essential on fuel tanks.

BURNERS

Burners for flaming cotton generally are in two categories: (a) Those designed for flaming the drill rows, and (b) those designed for flaming the middles. At least four manufacturers are currently making burners for drill-row flaming; some of these also make devices for flaming the middles.

Drill-row, or standard, burners are currently available in two basic designs: (a) The Stoneville flat-type burner developed at Stoneville, Miss., in 1949 (*12*), and (b) the AFCo burner developed by the Arkansas Foundry Co.[5] The AFCo burner is similar to the Stoneville burner except that the sides are designed to provide a "venturi" effect. Burners with pilots (to prevent "flameouts") or without them, and with vapor chambers (to make burners "self energized," and thereby eliminate a vaporizer in the main fuel line) or without them, are commercially available today.

Commercially available devices for flaming the middles consist principally of a lightweight hood or shield installed directly under the skid arm of a commercial burner carrier and two standard

[5] Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not consitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

burners mounted in front of the shield. The fuel cost for flaming middles with these devices is approximately the same as that of flaming the drilled area because two burners are used for each middle. Other devices for flaming middles of row crops were reported by Ball (*2*).

A successful burner for flaming the middles of cotton planted on 40-inch centers was designed and developed by USDA agricultural engineers at Stoneville, Miss., in 1962. This burner features a combustion chamber with adjustable vents, a hood that slides on the soil surface, and a heat-retainer flap attached to the trailing edge of the hood (fig. 6). A 21-inch version of the 27-inch burner was developed later to complete a two-row or a four-row flaming unit (fig. 7). Parts of the outside middles are flamed twice with this burner because flame paths overlap on successive passes over these middles. The amount of overlap depends on space between rows.

Except for the nozzles, fittings, and skids, both burners are made of 10-gage sheet metal. The 27-inch burner is equipped with two double-orifice nozzles, size 2–2503; the 21-inch burner, with two double-orifice nozzles, size 2–2502. These nozzles have worked satisfactorily with the inside orifice of each nozzle plugged by brazing.

For satisfactory operation, the Stoneville hooded burner requires about the same amount of fuel when equipped with the same size nozzle as the conventional burner. However, flaming the middles with hooded burners requires only slightly more than half the fuel per acre as it does to flame the drill rows with standard burners. Based on data in table 2 and operating pressures of 50 p.s.i., a four-row flaming unit equipped with eight standard burners using nozzles of orifice size 2–2503 would burn 29.20 gallons of fuel per hour; a four-row unit equipped with three 27-inch burners using nozzle size 2–2503 and with two 21-inch burners using nozzle size 2–2502 would burn 16.13 gallons of fuel per hour. This fuel consumption relationship would vary according to the stand density of the weeds to be killed.

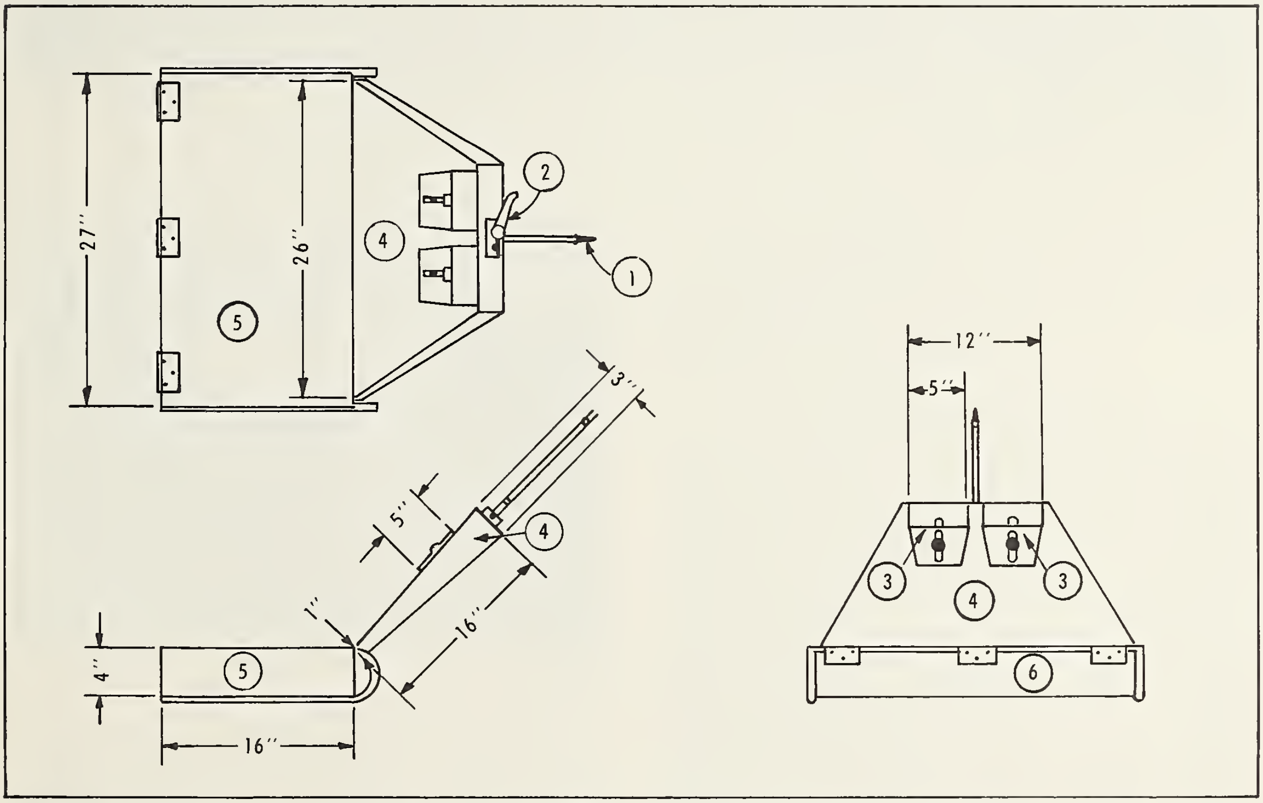

FIGURE 6.—Schematic diagram of the 27-inch Stoneville hooded burner designed for flaming the middles of cotton. Essential parts are: 1, fuel intake pipe; 2, two double-orifice nozzles; 3, adjustable vents; 4, combustion chamber; 5, hood; and 6, heat-retainer flap.

747-074 O - 65 - 2

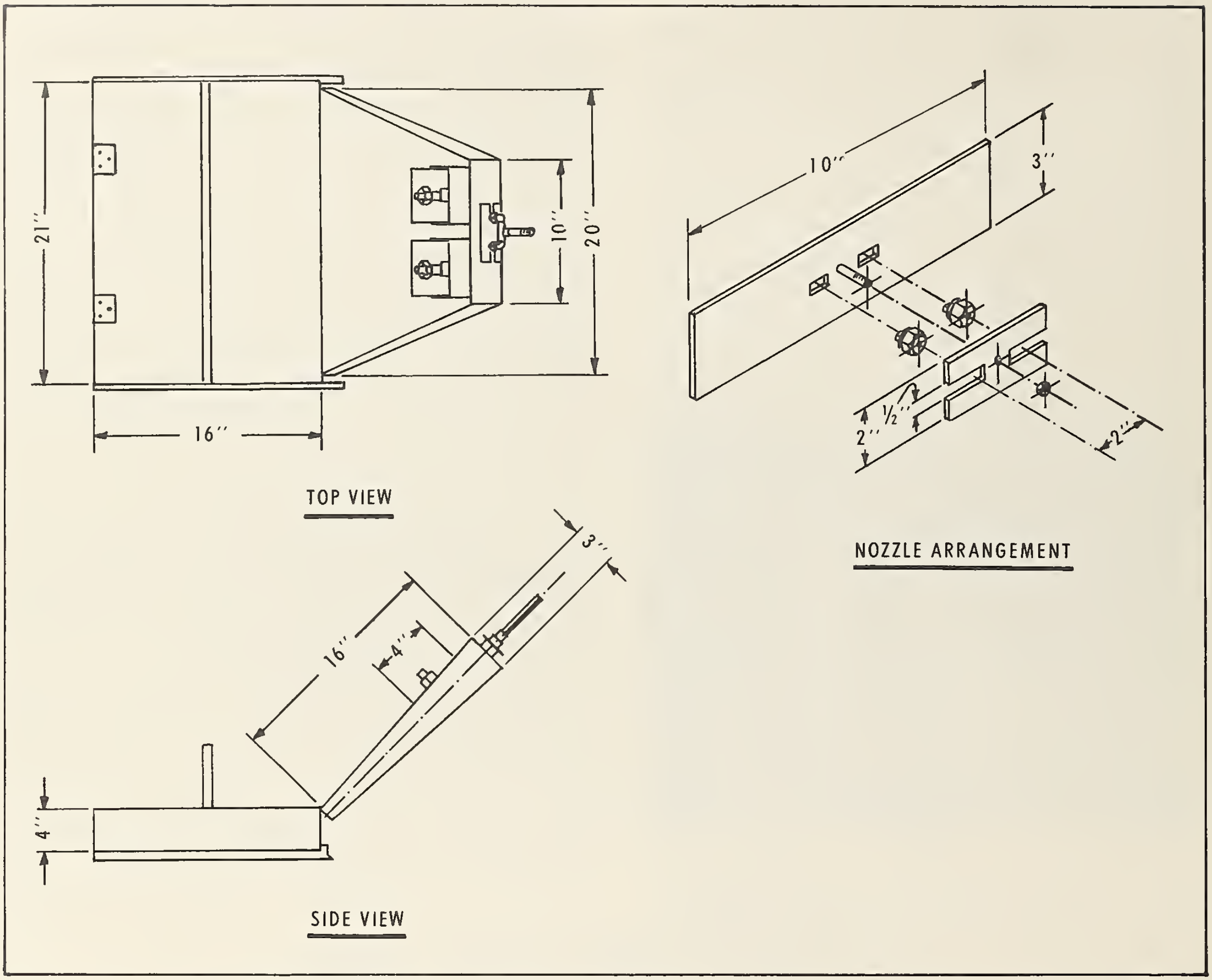

Figure 7.—Schematic diagram of the 21-inch hooded burner designed for flaming the outside middles, or "guess rows." The design is based on that of the original Stoneville hooded burner.

BURNER CARRIERS

The principal design of burner carriers has changed very little since our present flame-cultivation technique was developed. The disadvantages of mounting standard burners in the conventional manner have already been discussed (fig. 2). Recent progress in the development of standard burner carriers has been reported in the work of Parker and others (*10*). This work describes the advantages of controlling each burner separately by use of gage wheels. A standard burner and gage wheel mounted rigidly on the horizontal beam of a rear-mounted mechanical cultivator make it possible to maintain a constant distance between the burner and the soil surface (fig. 8).

The flame cultivator designed at Stoneville by Parker and Holstun (*9*) provides for individually gaged burners (fig. 9). The burner carrier was designed to provide the operator with maximum control of burner position and allow him to make simple burner adjustments. For parallel flaming, the burners are simply rotated 90° on the carrier (fig. 10).

The Stoneville hooded burner can be adapted to many types of carriers. The attachments needed to mount the burner on a rear-mounted mechanical cultivator are shown in figures 11 and 12. The

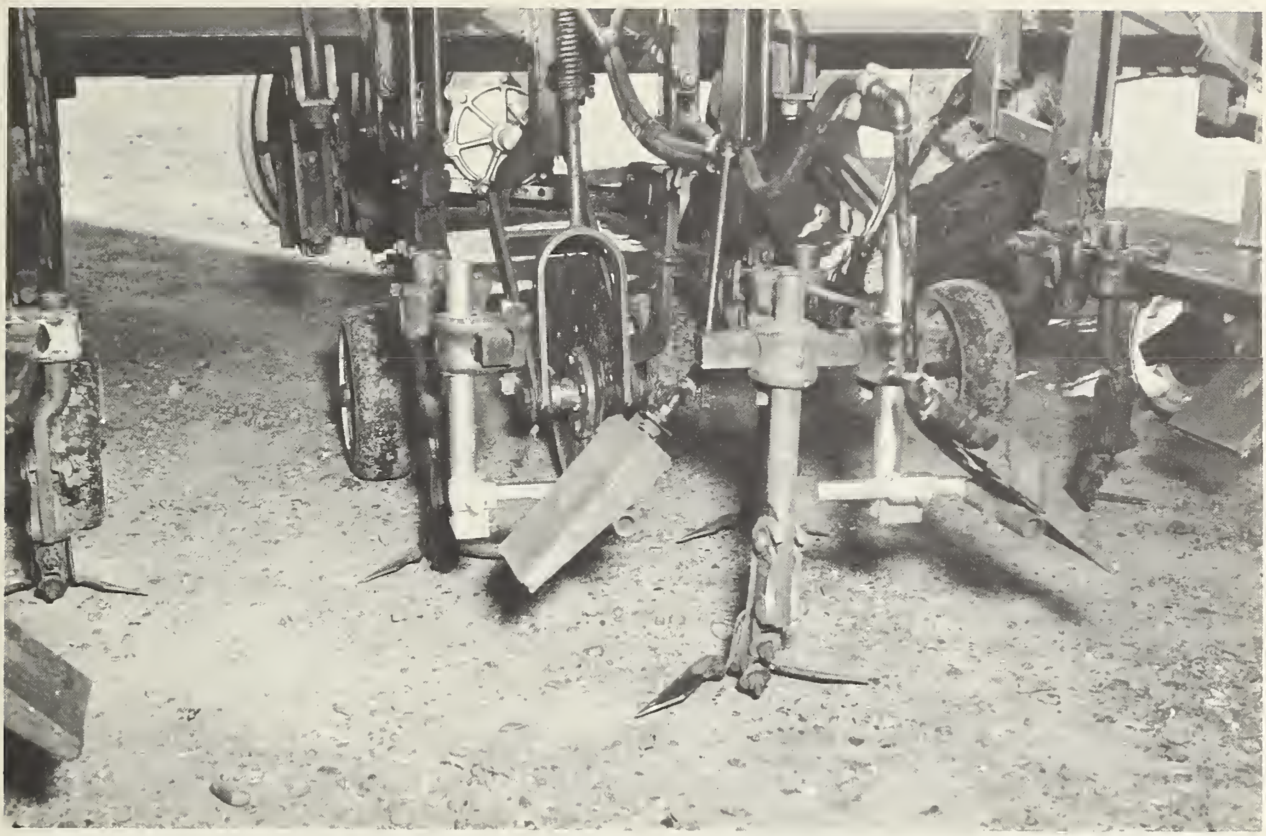

FIGURE 8.—Standard burners gaged individually are clamped to beam of a rear-mounted mechanical cultivator. This equipment allows middles to be cultivated and drill rows flamed in one operation.

FIGURE 9.—Burners positioned on Stoneville carriers for conventional flaming.

27-inch hooded burner, which was designed for flaming the inside middles of two- or four-row flaming equipment, is supported by two cultivator beams, which act independently of each other (fig. 11). The 21-inch, or outside-middle, burner is supported by only one cultivator beam (fig. 12). In addition, when in operation, all of the middle burners "float" independently of the cultivator beams.

The maximum use of flame for weed control at the minimum cost of equipment is obtained by mounting both middle and standard burners on a common carrier without sacrificing any of the desirable features of either. This objective was accomplished when the mount design of a standard burner developed by Parker and others (*10*) for a rear-mounted cultivator was combined with that of a middle burner described previously. The combined mounting of these two types of burners on a common beam is shown in figure 13. The crossarm originally designed for a length of 6 inches (*10*) was lengthened to 11 inches to allow offsetting the standard burners mounted opposite each other (fig. 14).

The design for mounting both types of burners on a common beam allows the position of the

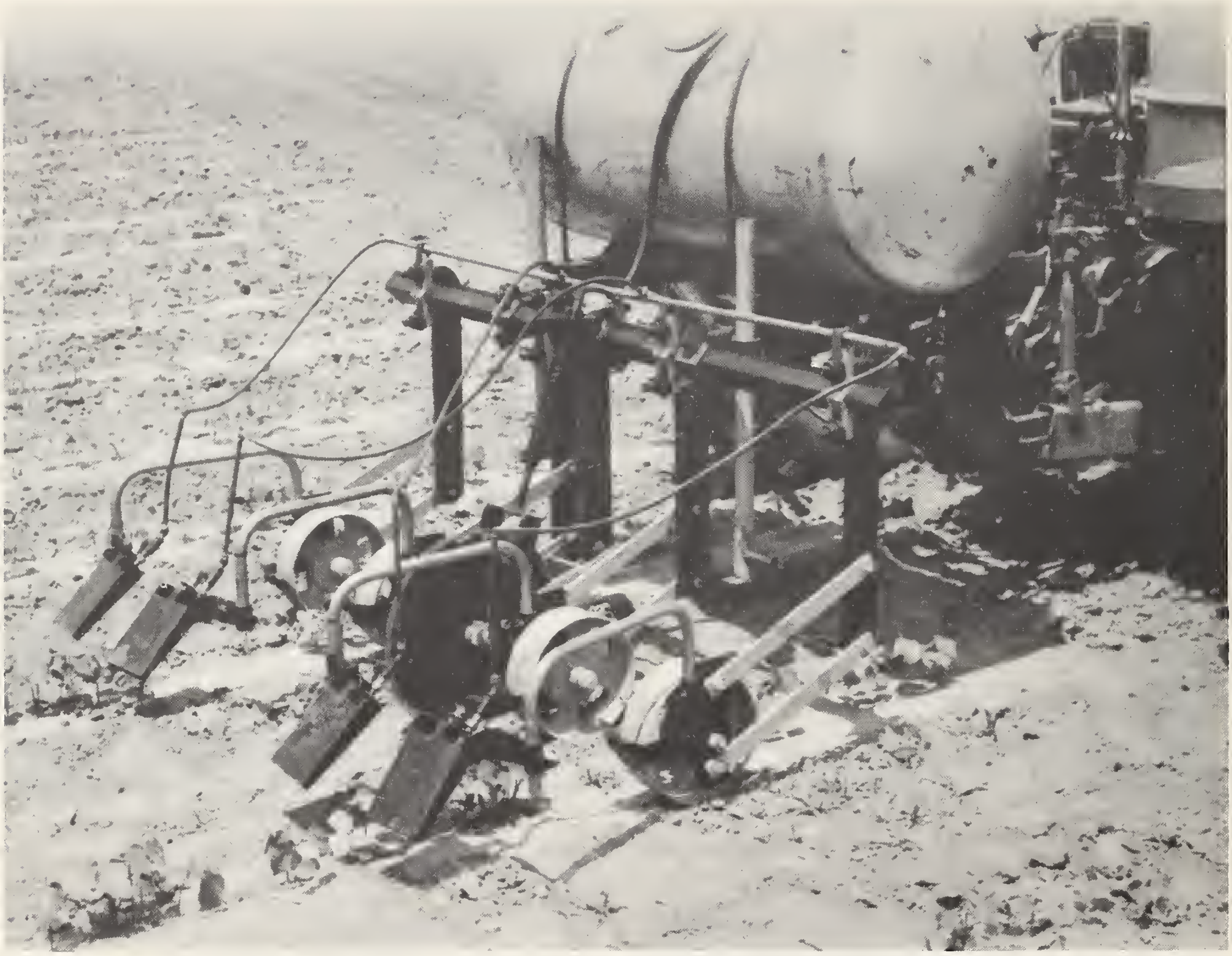

Figure 10.—Burners positioned on Stoneville carriers for parallel flaming.

standard burner to be controlled by the gage wheel and be independent of that of the middle burner (fig. 13). The arms that attach the middle burner to the beam can rotate freely at both ends and allow the cultivator beam to move up and down with changes in the soil level without a change in position of the middle burner. A two-row flaming unit is shown in figure 15.

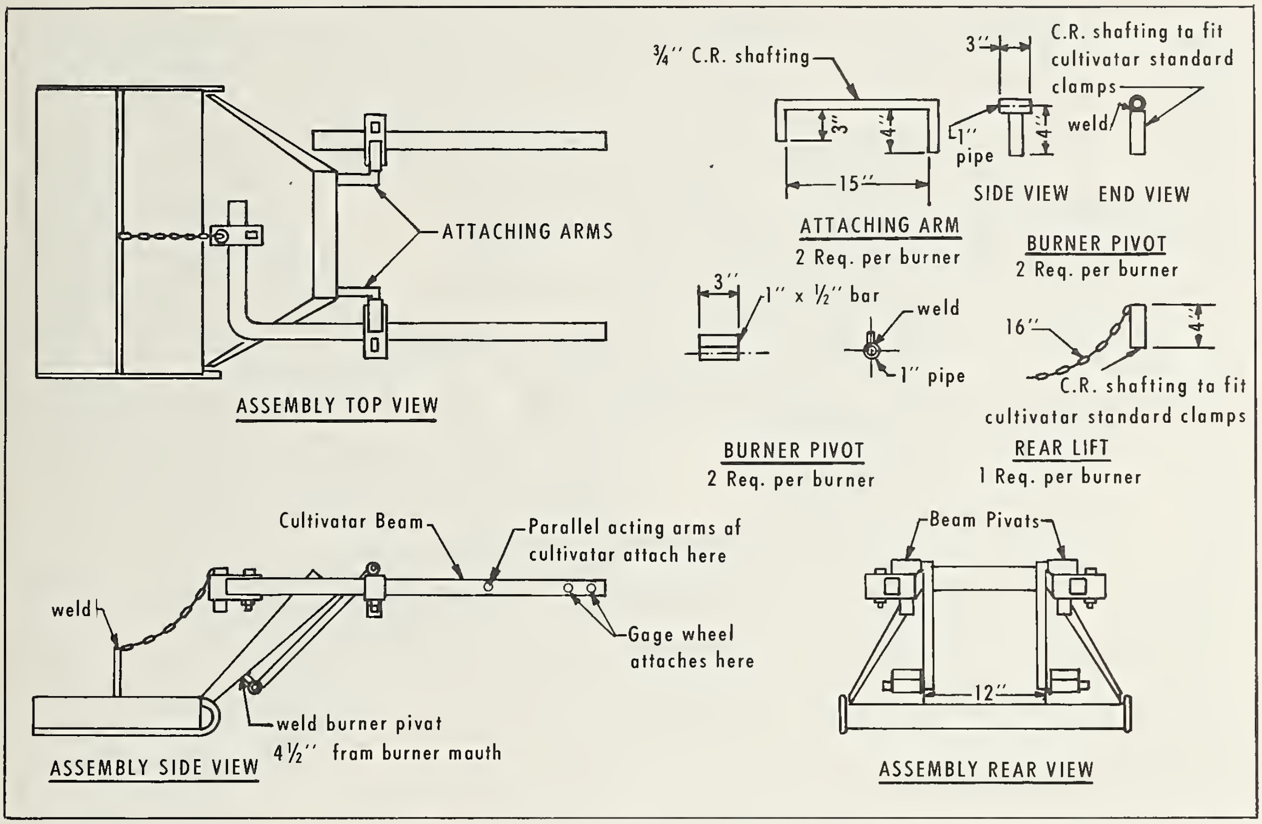

FIGURE 11.—A method of mounting the 27-inch Stoneville hooded burner on beams of a rear-mounted mechanical cultivator. The beams remain horizontal through use of parallel acting arms of the cultivator.

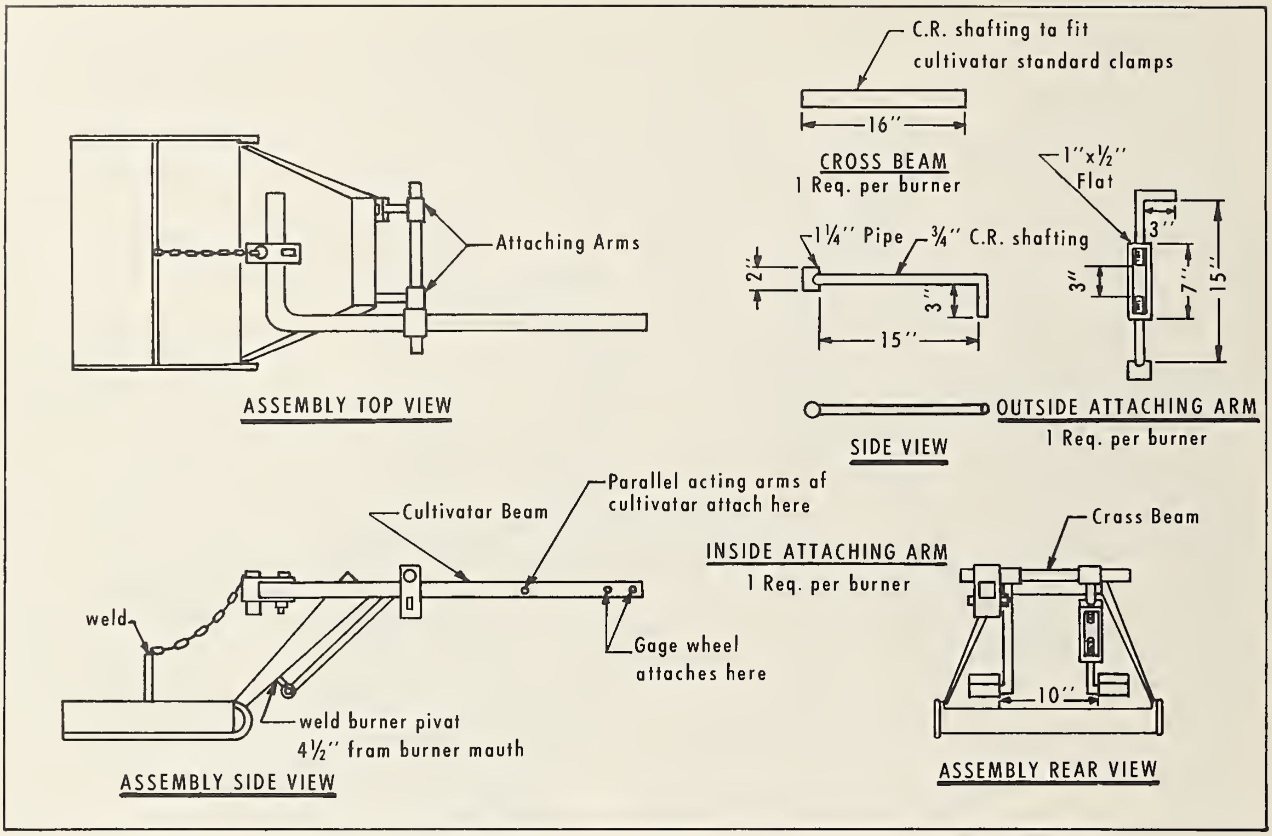

FIGURE 12.—A method of mounting the 21-inch, or outside-middle burner, on a rear-mounted mechanical cultivator. One of the attaching arms for each burner is adjustable, so that operator can aline burner to the direction of travel.

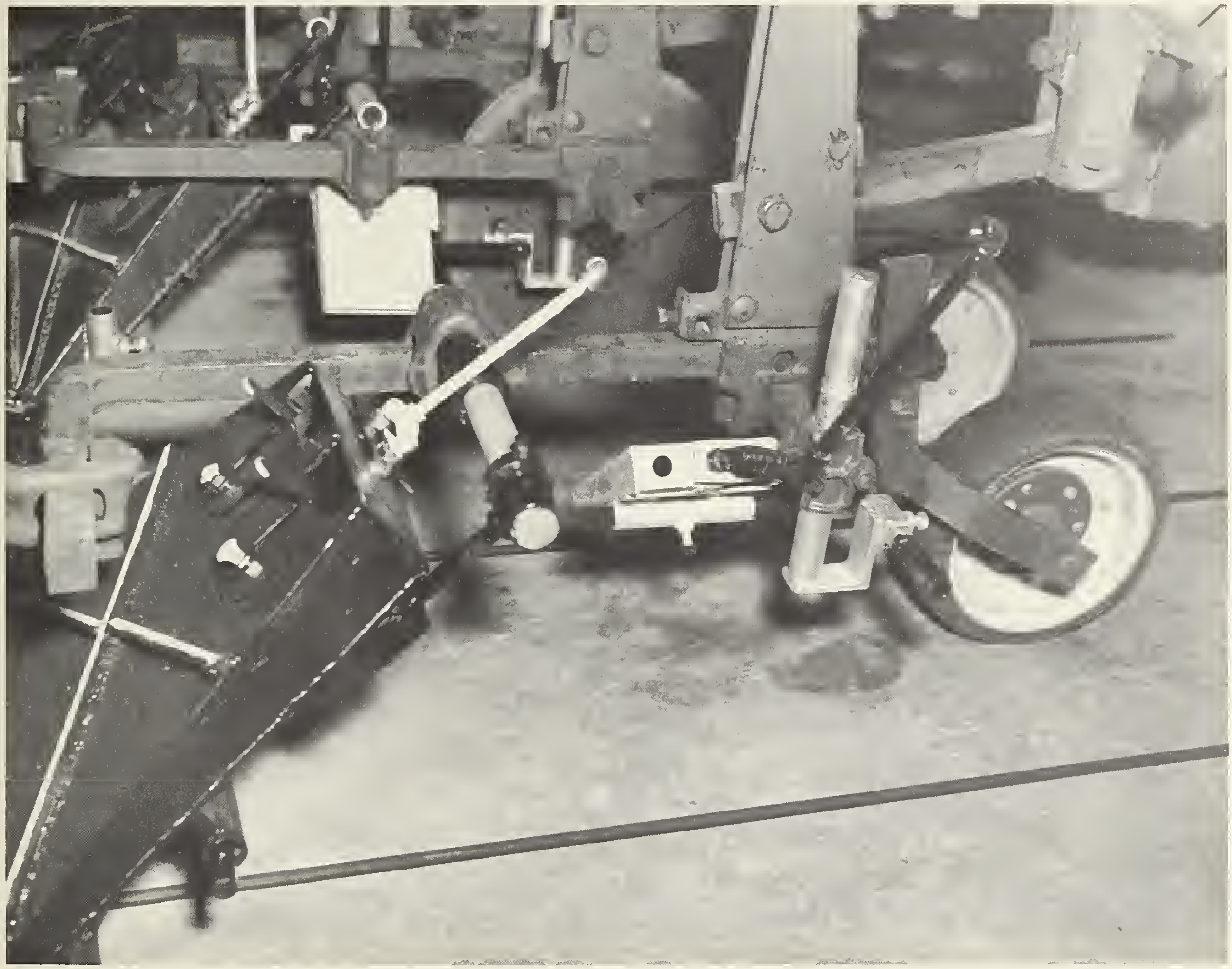

FIGURE 13.—Middle burners and standard burners mounted on a common beam. They act independently when in operation. The height of the standard burner is always controlled by the gage wheel.

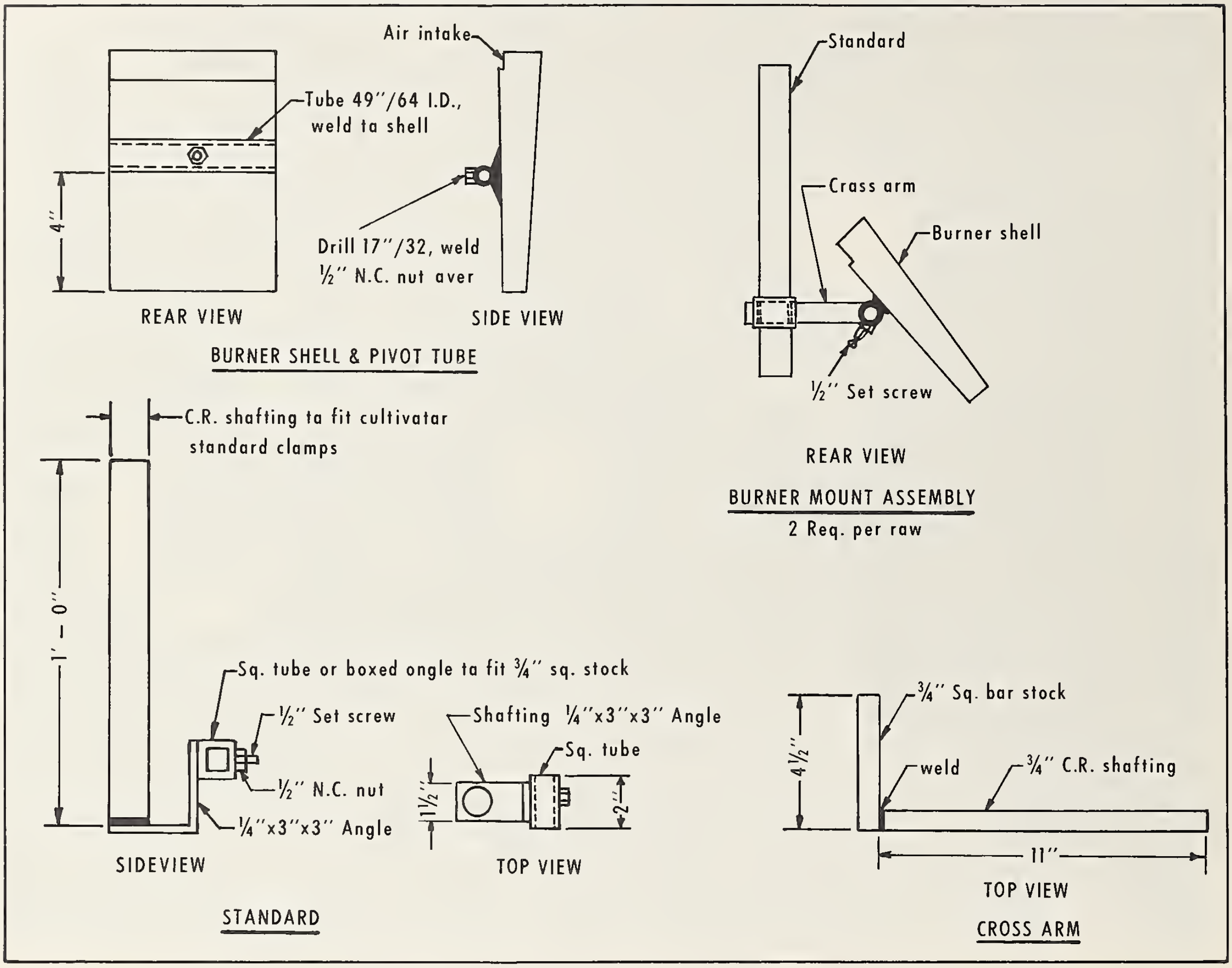

Figure 14.—Schematic diagram of attachments for mounting standard burners on a mechanical cultivator.

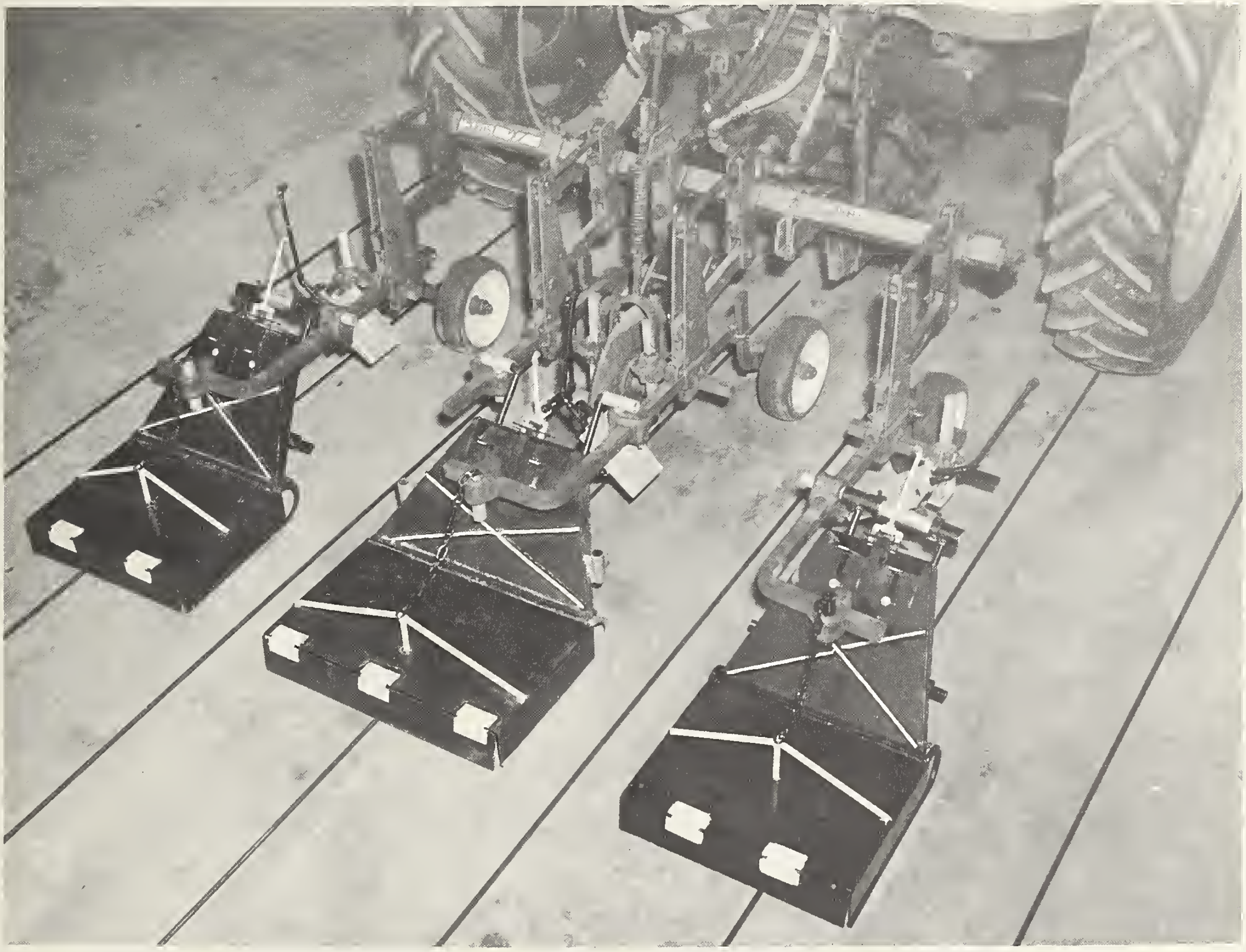

FIGURE 15.—A complete two-row flaming unit consisting of middle burners and standard burners attached to a rear-mounted mechanical cultivator. When in operation, all burners act independently of each other.

LITERATURE CITED

(1) ANONYMOUS.
1958. WEED CONTROL RECOMMENDATIONS. Miss. Agr. Expt. Sta. Bul. 556.

(2) BALL, C. E.
1963. NEW WAYS TO CLEAN UP GRASSY COTTON. Farm Jour. 87 (6): 22.

(3) CARTER, L. M., COLWICK, R. F., and TAVERNETTI, J. R.
1960. EVALUATING FLAME-BURNER DESIGN FOR WEED CONTROL IN COTTON. Amer. Soc. Agr. Engin. Trans. 3 (2): 125–128.

(4) HOLSTUN, J. T., JR., WOOTEN, O. B., MCWHORTER, C. G., and CROWE, G. B.
1960. WEED CONTROL PRACTICES, LABOR REQUIREMENTS AND COSTS IN COTTON PRODUCTION. Weeds 8: 2.

(5) HOLSTUN, J. T., JR., HARRIS, V. C., and MOORE, C. E.
1963. WEED CONTROL RECOMMENDATIONS FOR COTTON. Miss. Agr. Expt. Sta. Bul. 660.

(6) LEWIS, BERNARD, and VON ELBE, GUENTHER.
1951. COMBUSTION, FLAMES AND EXPLOSION OF GASES. 766 pp., Academic Press Inc., New York.

(7) OBERT, E. F.
1950. INTERNAL COMBUSTION ENGINES. Ed. 2, 218–219. International Textbook Co., Scranton, Pa.

(8) PARKER, R. E., and HOLSTUN, J. T., JR.
1961. PARALLEL VERSUS CONVENTIONAL FLAMING FOR WEED CONTROL IN COTTON. Miss. Farm Res. April.

(9) ——— and HOLSTUN, J. T., JR.
1963. NEW DEVELOPMENTS IN FLAME CULTIVATION. Amer. Soc. of Agr. Engin. Proc. (Southeast. sect., Memphis, Tenn.)

(10) PARKER, R. E., WOOTEN, O. B., and WILLIAMSON, E. B.
1962. FIELD EVALUATION OF TWO TYPES OF FLAME BURNER MOUNTINGS. U.S. Dept. Agr. ARS 42–60.

(11) STEPHENSON, K. Q.
1959. MECHANIZED WEED CONTROL IN COTTON. Ark. Farm Res. May–June, pp. 6–7.

(12) WILLIAMSON, E. B., WOOTEN, O. B., and FULGHAM, F. E.
1956. FLAME CULTIVATION. Miss. Agr. Expt. Sta. Bul. 545.

U. S. GOVERNMENT PRINTING OFFICE : 1965 O - 747-074